

PRELIMINARY

**Bell System Data Communications
TECHNICAL REFERENCE**

Data Access Arrangement

November 1968

ENGINEERING DIRECTOR - DATA COMMUNICATIONS
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PREFACE

The material in this Technical Reference is intended for use by designers and manufacturers of data modulation and demodulation (modem) devices which will electrically couple data signals into the switched message network. This material covers design guides for electrically coupled modems which, if followed, should permit the transmission of data signals without interference to other Telephone Company services.

In furnishing this material, the Bell System makes no claims or representations and assumes no responsibility for the suitability of the transmission path or the performance of systems using customer provided data modems, other than that the telephone facilities employed are suitable for satisfactory voice and/or DATA-PHONE^R communications. In addition, the Bell System is in no way responsible for the design or performance of customer provided data modems electrically coupled to the switched message network and does not endorse or approve any customer provided data modems. The material in this Technical Reference is intended to be helpful to data modem designers in the interest of preventing interference to other Telephone Company services, and is not intended to provide complete design specifications or parameters for data modems.

This document will be updated as arrangements that provide additional features become available and further information about the switched message network becomes available.

R - Registered Service Mark

1. GENERAL

The Bell System has recently filed revised intrastate and interstate tariff regulations that pertain to connection of customer provided data transmitting and receiving equipment. These changes, should they be permitted to become effective, would provide for the electrical connection of customer provided data transmitting and receiving equipment to the switched message network through a Data Access Arrangement.

This arrangement provides a means to connect customer provided modems to the switched network. All modulating and demodulating functions are to be performed by the customer's equipment, but the Bell System retains responsibility for network control signaling (this includes furnishing switch hook, dialing and control functions). The data signal format (such as serial or parallel; binary or multi-level; FM, AM or PM; digital or analog) will be the modem manufacturer's option. In addition to data signals, customer-provided equipment may input machine-generated voice signals or possibly live speech.

The particular implementation of the Data Access Arrangement described in this Technical Reference provides a protective connecting arrangement as the interface between a customer provided modem and the switched message network. Other implementations of the Data Access Arrangement will be described in subsequent issues.

2. SYSTEM DESIGN CONSIDERATIONS

2.1 Data Access Arrangement

The data access arrangement, shown in Figure 1, allows

customers to transmit and receive data over the switched message network with their own data modems. The telephone set, equipped with a data key, provides the proper signaling functions required for call origination and answering. The protective connecting arrangement ascertains that the electrical signals from the modem do not exceed the level restrictions which are necessary in order to prevent interference with other telephone services. Later versions may have automated features such as unattended answering of calls and compatibility with Automatic Calling Units.

2.2 Service and Maintenance Considerations

The testing and maintenance operations performed by the Telephone Company on its apparatus and line facilities will be limited to those necessary to assure that the transmission parameters are equivalent to those provided for DATA-PHONE service. The customer is responsible for the testing and maintenance of his equipment and verification of his operational procedures.

2.3 Echo Suppressor Considerations

Many customer-provided data modems may have the capability to transmit and receive data simultaneously. This feature is commonly known as "duplex" operation, as opposed to "half-duplex" operation where a modem is either transmitting or receiving at any given time.

Within the switched message network there may be separate paths for the two directions of transmission. In voice communications at least one of the paths is usually idle at any given time. In order to protect the person who is talking from hearing a disturbing "echo" of his voice on long distance calls, the idle receive path is attenuated by a device called an "echo suppressor". As a result, voice or data signals may only be transmitted in one direction at a time under normal conditions. If duplex operation is desired, the echo suppressor must be disabled by the modem.

The echo suppressor may be disabled by applying a single frequency tone the level of which is in the range of 0 to 5 dB below the maximum specified data signal level somewhere in the band 2010-2240 Hz for at least 400 milliseconds. The subsequent data signal will keep the echo suppressor disabled as long as interruptions in signals are less than 100 milliseconds in duration.

The "turn-around" time of echo suppressors is a characteristic which concerns the half-duplex operation of data modems. A modem which is receiving half-duplex signals from a distant modem should not begin transmitting at the instant the distant modem ends transmission. This restriction is caused by the delay in the removal of the high attenuation placed in the receive path by the echo suppressor. This delay, called "turn-around" time, is usually about 100 milliseconds. This is illustrated diagramtically in the Technical Reference for the

Data Sets 202C and 202D. Additional information concerning echo suppressors and disabling may be found in the references listed in Section 9. Technical References describing the characteristics of DATA-PHONE data sets can be obtained by contacting:

Engineering Director - Data Communications
American Telephone and Telegraph Company
195 Broadway
New York, New York 10007

2.4 Impedance of the Modem

The impedance of the modem, whether transmitting or receiving, should be a nominal 600 ohms over those portions of the frequency spectrum used by the data signal transmitted by the modem. The modem's impedance at other frequencies in the voiceband should result in a minimum return loss of about 7 dB when measured against a nonreactive resistor of 600 ohms. Conformance to this requirement will standardize the impedances used in power measurements and tend to mitigate the noise encountered in transmission.

2.5 AC Voltage Protection

There are protective devices located at the station that will limit lightning surges and AC voltages that exceed 600 volts. Since the data modem is connected to the telephone line through the protective connection arrangement, the modem is protected from longitudinal lightning surges by transformer isolation. The maximum metallic surge due to lightning the modem will encounter is 25 volts.

3. DESCRIPTION OF THE DATA ACCESS ARRANGEMENT

3.1 Physical

The data access arrangement is equipped with a standard

telephone set for the manual origination and reception of data calls, in the same manner as normal voice telephone service. The protective connecting arrangement uses telephone line power, is wall mounted, 4-3/4" in width, 7-3/4" in height, 1-3/4" in depth and weighs approximately 1-1/4 lbs. It is currently designed to operate over a temperature range from 40° to 120°F and a humidity range from 20 to 95 percent.

The maximum signal input power which the protective connecting arrangement accepts will be specified by the Telephone Company at the time of installation. The specification will range from 0 to -12 dBm, into 600 ohms in 1 dB steps, depending on the loss between the local telephone office and the station. Two screw terminals are provided on the protective connecting arrangement to permit electrical connection to a customer provided modem as shown in Figure 1.

3.2 Functions

The data access arrangement is diagrammed in Figure 2. The major functions of these circuits are:

- a. To provide an access for customer provided modems to the switched message network.
- b. To provide necessary features for network control signaling.
- c. To allow attendants to manually transfer control of the telephone line between the telephone set and the customer provided data modem.
- d. To limit signals below a specified value, if the customer's power level is too high in order to prevent overloading of telephone facilities.

- e. To protect personnel from injury and equipment from damage due to hazardous voltages.

Data Key Circuit - The attendant can transfer control of the telephone line to the modem by lifting the data key of the telephone set.

Limiter - Protection from excessive power levels is accomplished by a circuit that averages the signal power generated by a modem over a period of approximately any 3-second interval. If the average power exceeds the prescribed limit, a nonlinear limiting device is shunted across the line which may result in severe distortion of the data signals.

4. ELECTRICAL CHARACTERISTICS OF THE PROTECTIVE CONNECTING ARRANGEMENT

4.1 Input Impedance

The input impedance in the "talk" (or "idle") mode is at least 100 ohms. The magnitude of the input impedance of the protective connecting arrangement in the "data" mode will be nominally 600 ohms. However, the input impedance in the "data" mode is essentially a 600 to 900 transformation of the impedance of the telephone line, which varies from line to line and is frequency dependent. Because of these variations, a modem should be capable of driving impedances in the "data" mode that typically have resistive components which may vary from about 100 ohms to 900 ohms, and capacitive reactive components that may vary from 0 to about 700 ohms. Impedances outside this range will occasionally be encountered.

4.2 Input-Output

The input-output characteristics of the protective connecting arrangement are:

Insertion loss - nominally 2 dB

Insertion loss deviation - 300 Hz to 500 Hz - 1 dB

500 Hz to 3000 Hz - .5 dB

Envelope Delay Distortion - 1000 Hz to 2400 Hz - 20 microsec.

500 Hz to 3000 Hz - 50 microsec.

Nonlinear Distortion - Nominally the harmonic energy in the band 300 Hz to 3000 Hz is at least 50 dB below the fundamental

Any distortion of the data signal by the protective connecting arrangement will be negligible compared to the distortions encountered on a typical data call using the switched message network.

5. MODEM SIGNAL RESTRICTIONS

5.1 Signal Power

Endeavoring to provide satisfactory transmission performance and to prevent interference to other telephone services, certain requirements must be placed on the electrical characteristics of the signals from a customer's modem

The average power of the signal transmitted by a modem over any 3-second interval should not exceed a level prescribed by the Telephone Company at the time of installation. This level will range between 0 dBm and -12 dBm into 600 ohms (depending

on line loss) and will be specified in steps of 1 dB. The objective is to obtain a signal level of no more than -12 dBm at the local central office. This maximum input signal level to the protective connecting arrangement will be displayed on the equipment, as shown in Figure 1.

The power in the band from 3,995 hertz to 4,005 hertz should be at least 18 dB below the power of the signal as specified in the paragraph above. The power in the band from 4000 to 10,000 Hz should not exceed 16 dB below one milliwatt. The power in the band from 10,000 Hz to 25,000 Hz should not exceed 24 dB below one milliwatt. The power in the band from 25,000 to 40,000 Hz should not exceed 36 dB below one milliwatt. The power in the band above 40,000 Hz should not exceed 50 dB below one milliwatt.

5.2 Signal Power Distribution

The switched message network incorporates tone signaling devices that are used for network control functions. These devices, connected at all times to the telephone circuit, are designed to be sensitive to single frequency tones at 2600 Hz. They are relatively insensitive to energy at these frequencies if sufficient energy is present at the same time at other frequencies in the voiceband.

In order to prevent the interruption or disconnection of a call, or interference with network control signaling, it is necessary that the signal applied by the customer-provided equipment to the protective connecting arrangement at no time have energy solely in the 2450 to 2750 Hz band. If signal

power is in the 2450 to 2750 Hz band, it must not exceed the power present at the same time in the 800 to 2450 Hz band.

5.3 DC Signals

The data modem should not present direct current into the protective connecting arrangement as transformers are used as input devices and direct currents may cause distortion of the data signal.

6. PLACING A DATA CALL

A data call using a data access arrangement is placed in a similar manner to a regular call. To initiate a call, the attendant lifts the handset of the associated telephone set, receives dial tone, and dials the telephone number of a distant telephone set associated with another data access arrangement or a DATA-PHONE data set.

The call at the receiving station is answered in a normal manner. For manual answering, both stations are in the "talk" (or "idle") mode. The attendants then verify that both ends are ready to transmit and receive data. When both modems are ready, the attendants operate the data keys and the modems may transmit and receive data. If the call is to an automatic answering DATA-PHONE data set, upon recognition of the answer signal, the attendant operates the data key and the modems may transmit and receive data. At the completion of transmission, the attendants should return the data keys to their initial positions and hang up the handset.

7. SWITCHED MESSAGE NETWORK CHARACTERISTICS

7.1 Transmission Parameters

A good deal of information describing the component parts and operating characteristics of the switched message network has been published. The system characteristics usually of interest for data transmission were published in the Bell System Technical Journal in May 1960 as an article entitled:

"Capabilities of the Telephone Network
for Data Transmission"

By A. A. Alexander

R. M. Gryb

D. W. Nast

This information was also released as Monograph 3580 and is included in the "Bell System Data Communications - Technical Reference Manual".

The article provides statistical information on the ranges of amplitude and frequency responses, envelope delay-frequency characteristics, net loss, and thermal and impulse noise distributions, which can be encountered over the switched message network.

7.2 Expected Level of Received Signals

The end-to-end loss at 1000 Hz on a call between two stations equipped with data access arrangements is a function of the insertion losses of the protective connecting arrangements at both stations, the insertion losses of the loops at both ends, the end-office to end-office loss encountered over the switched message network.

As stated in Section 4.2, the nominal insertion loss of a protective connecting arrangement is 2 dB. However, the 1000 Hz insertion losses of loops can vary over a range from 0 to 10 dB, in some cases, as discussed in Section 9, Reference i.

The 1000 Hz loss encountered from end-office to end-office is a function of distance and can range from 0 to 25 dB, in some cases, as discussed in Section 9, Reference g.

With the signal level at the transmitting local office set to -12 dBm, the level at the receiving modem will be a function of the end-office to end-office loss, the receiving loop loss, and the loss of the receiving protective connecting arrangement. As a result, in the worst case, the received signal level at the modem could be:

$$\text{received signal level (1000 Hz)} = -12 \text{ dBm} - 25 - 10 - 2 = -49 \text{ dBm}$$

A specific distribution for received levels may be calculated in the following manner. If a calling pattern is such that it is equally likely to make a short, medium or long haul call, then the distribution of the losses at 1000 Hz encountered between end-offices will have a mean of about 8.5 dB and a standard deviation of about 3 dB.

If the modems are connected to business telephone loops, then the loss distribution for each loop will have a mean loss of about 2.5 dB with a standard deviation of about 2 dB.

As a result, under the assumptions outlined above, 1000 Hz signals on calls with this calling pattern and received over business telephone loops, will be received at the modem with levels which are distributed with a mean of about -25 dBm and a standard deviation of about 4 dB.

It should be emphasized that the above loss distribution was computed for a particular case. In general, the References in Section 9 should be consulted for specific types of calling patterns, loop distributions, and losses at other frequencies.

A connection over the switched message network between two modems is sketched in Figure 3.

8. SUPPLEMENTARY TRANSMISSION PARAMETERS

8.1 General

Information on the following transmission parameters is limited. They are presented here so that modem manufacturers might have an appreciation of their effect. It must be stated that the values presented are expected and are not the current maintenance limits of the Bell System.

8.2 Frequency Shift

Most long and some short haul carrier systems used in the switched message network operate in a single sideband suppressed carrier mode. Because the carrier is not transmitted and must be re-inserted locally, there can be differences in frequency between the modulating and demodulating carriers. This gives rise to frequency error since the received frequency will be somewhat different than the transmitted frequency. This effect can degrade some data demodulation processes and can cause high distortion in very narrow band frequency division multiplex systems.

The Bell System uses a frequency lock system in long haul carrier systems which holds the frequency shift per facility section to no more than ± 1 Hz. Therefore, the extreme frequency error on an end-to-end connection is in the order of ± 10 Hz.

8.3 Phase Jitter

The instantaneous phase of the received data signal is likely to jitter at rates typically of 180 Hz and below causing sidebands with magnitudes of approximately 18 dB below the level of the carrier. This effect is primarily caused by ripples in the dc power supply appearing in the master oscillator of long haul carriers and being multiplexed through many stages. Some phase jitter also occurs in short haul systems from imperfect filtering of spurious energy from one carrier repeater section to another. A digital carrier system will also exhibit jitter at specific frequencies.

8.4 Nonlinearities

Nonlinearities such as compression, clipping and harmonic distortion can exist on communications facilities and equipment. Normally, these are low enough so that data sets are unaffected. Where high speed operation is contemplated (1000 bauds; 2000 bits), these distortions may be controlling. It is expected that harmonic distortions no greater than 5 percent of the fundamental frequency will normally be encountered on the switched message network.

8.5 Gain and Phase Hits

Sudden changes in the level and phase of the received signal may be encountered. Modems should be able to withstand level changes of +3 dB and phase changes of +90 degrees. The occurrence of such events is rare (on the order of 30 per day per circuit) but should be recognized by the modem designer.

8.6 Dropouts

Momentary large drops in signal levels or degradations in signal to noise ratios due to fading and switching on microwave radio systems should be expected. The duration of these dropouts are usually on the order of milliseconds for large changes in level and in the order of seconds for relatively small changes.

9. REFERENCES

Some references describing various transmission characteristics of the Switched Message Network are listed below. These references should prove useful to the designers of data modems.

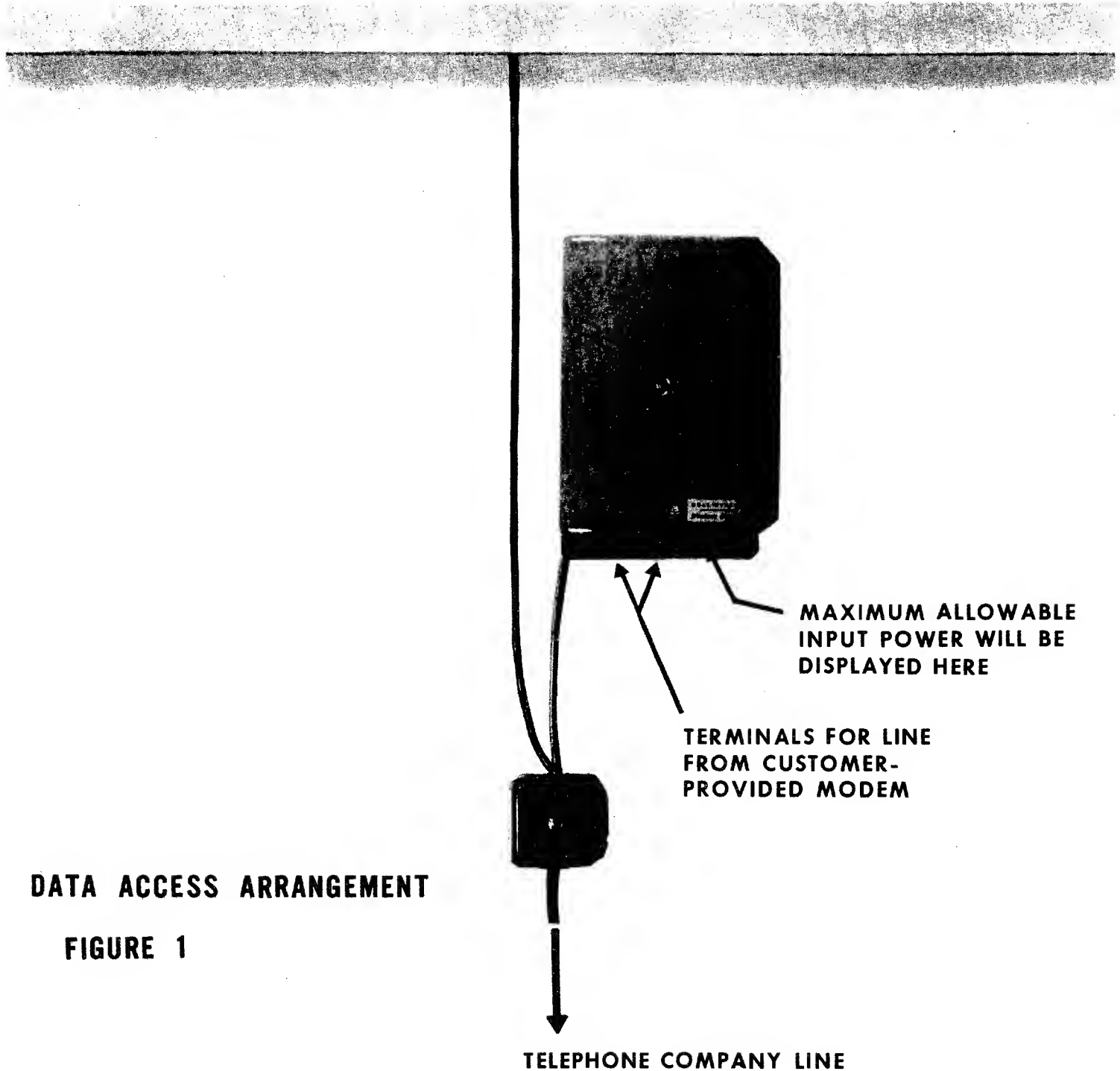
- a. Breen, C., and Dahlbom, C. A., "Signaling Systems for the Control of Telephone Switching," BSTJ, 39, No. 6 (November 1960) P. 1381.
- b. Brady, P. T. , and Helder, G. K., "Echo Suppressor Design in Telephone Communications," BSTJ, 42, No. 6 (November 1963), P. 2893.

- c. Bugbee, L. F., "A Tone Disabler for Bell System 1A Echo Suppressor," AIEE Transactions, Part 1 - Communications and Electronics, No. 58 (January 1962), P. 596.
- d. Morris, R., "Further Analysis of Errors Reported in 'Capabilities of the Telephone Network for Data Transmission'" BSTJ, 41, No. 4 (July 1962), P. 1399.
- e. Nasell, I., "The 1962 Survey of Noise and Loss on Toll Connections," BSTJ, 43, No. 2 (March 1964), P. 697.
- f. Townsend, R.L. and Watts, R. N., "Effectiveness of Error Control in Data Communication Over the Switched Telephone Network," BSTJ, 43, No. 6 (November 1964), P. 2611.
- g. Nasell, I., "Some Transmission Characteristics of Bell System Toll Connections," BSTJ, 47, No. 6 (July-August 1968), P. 1001.
- h. Bodle, D. W. and Gresh, P. A., "Lightning Surges in Paired Telephone Cable Facilities," BSTJ, 40, No. 2 (March 1961), P. 547.
- i. Hinderliter, R. G., "Transmission Characteristics of Bell System Subscriber Loop Plant", IEEE Transactions, Communications and Electronics, (September 1963), P. 464.

- j. Elliott, E. O., "A Model of the Switched Telephone Network For Data Communications", BSTJ, 44, No. 1 (January 1965), P. 89.
- k. Nasell, I., Ellison, C.R., And Holmstrom, R., "The Transmission Performance of Bell System Intertoll Trunks", BSTJ, 47, No. 8 (October 1968), P. 1561.
- l. Fennick, J. H., And Nasell, I., "The 1963 Survey of Impulse Noise on Bell System Carrier Facilities", IEEE Transactions on Communications Technology, COM-14, No. 4 (August 1966), P. 520.



DATA KEY



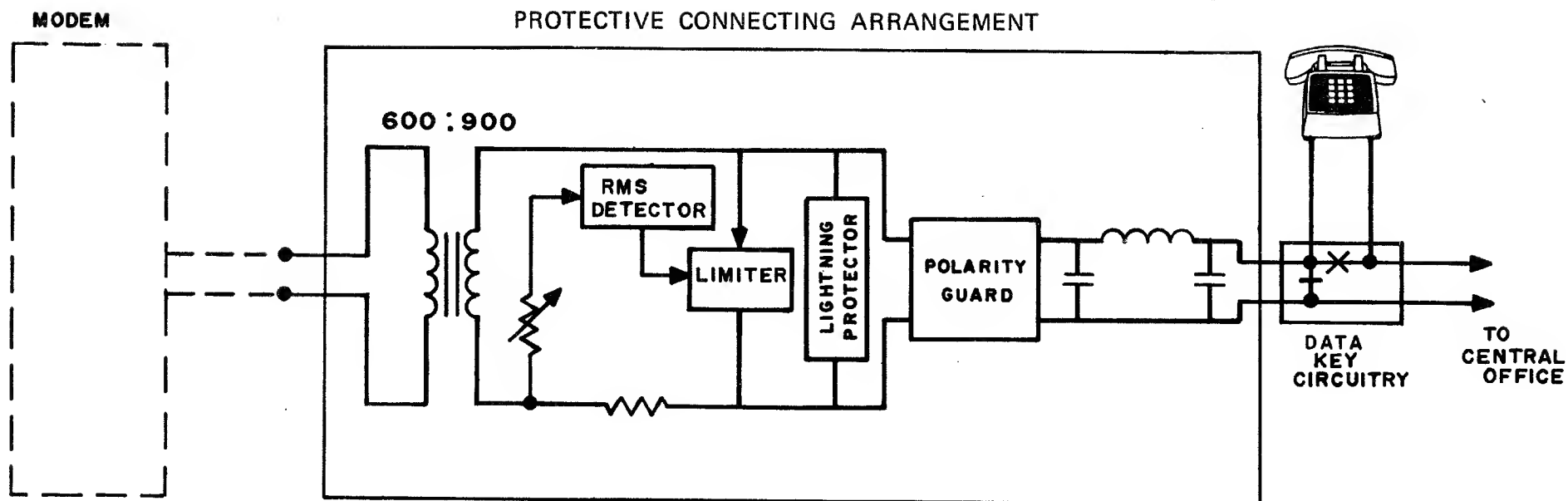
MAXIMUM ALLOWABLE
INPUT POWER WILL BE
DISPLAYED HERE

TERMINALS FOR LINE
FROM CUSTOMER-
PROVIDED MODEM

DATA ACCESS ARRANGEMENT

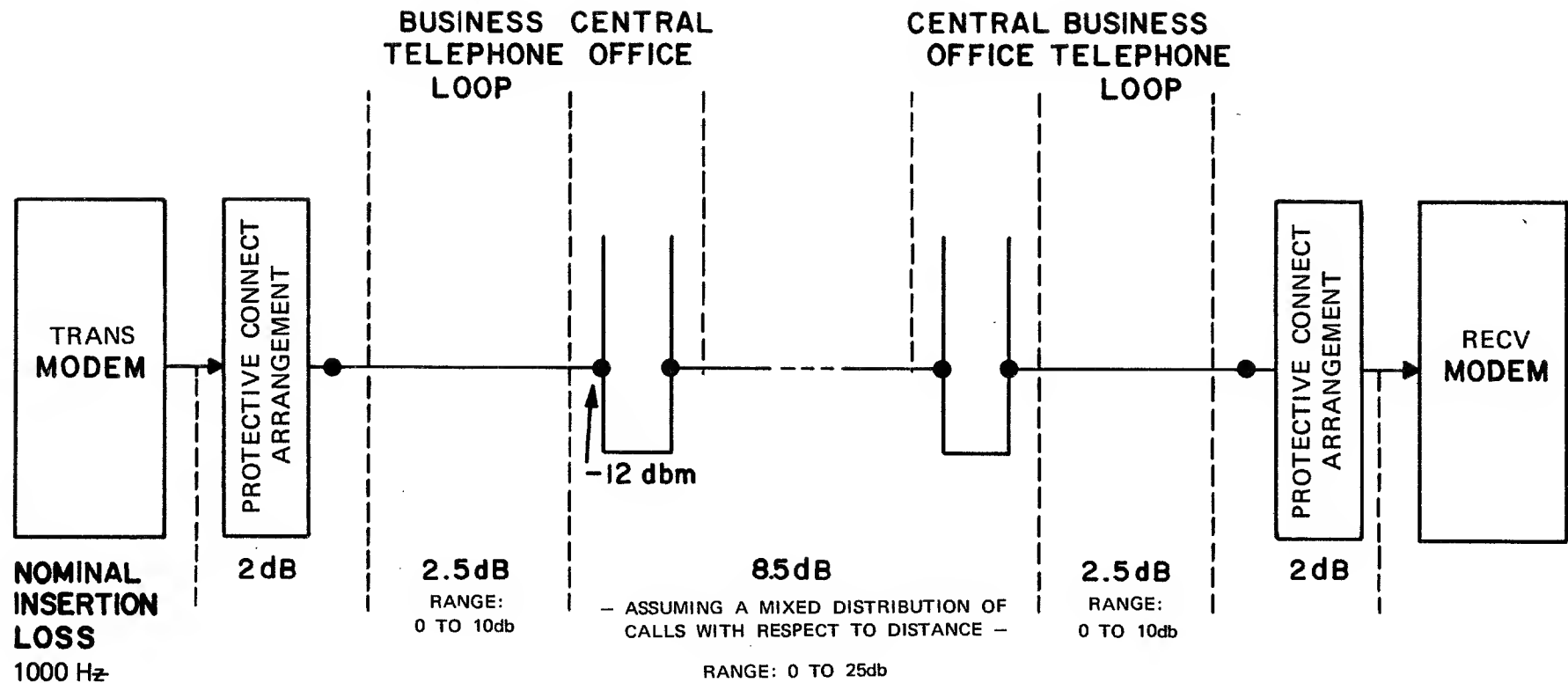
FIGURE 1

TELEPHONE COMPANY LINE



**BLOCK DIAGRAM OF THE
DATA ACCESS ARRANGEMENT CIRCUITS**

FIGURE 2



**TYPICAL DATA CALL USING THE
DATA ACCESS ARRANGEMENT**

FIGURE 3